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CONTROL OF THE GRAPE-BERRY MOTH IN NORTHERN OHIO.

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INTRODUCTION.

The grape-berry moth (*Polychrosis viteana* Clem.) has been the most destructive insect pest with which the grape growers of northern Ohio have ever had to contend. In an effort to improve the methods of control for this insect, extensive experiments in cooperation with the Ohio Agricultural Experiment Station were conducted during the seasons of 1916, 1917, and 1918 in northern Ohio. The results of these experiments and the recommendations based thereon are contained in this paper, together with observations made during the investigation. Only such life-history data are presented as are necessary for the understanding of the control experiments. The complete life-history data will be presented in a later paper.

[1] This investigation was conducted under the direction of Dr. A. L. Quaintance, Entomologist in Charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. The senior author, assisted by E. R. Selkregg, then field assistant in the Bureau of Entomology, conducted the work during the season of 1916. Much credit is due Dwight Isely of the Bureau of Entomology for his suggestions on grape-insect control, based on similar investigations in the Chautauqua-Erie grape belt of Pennsylvania. The results of Mr. Isely's investigations are published in United States Department of Agriculture Bulletin No. 550. The authors wish to express their appreciation to Prof. H. A. Gossard, entomologist of the Ohio Agricultural Experiment Station, for his help in many ways. To the many grape growers who have cooperated most willingly the authors express their thanks.

HISTORY IN OHIO.

The grape-berry moth was destructive in Ohio as early as 1869, according to Goodwin.[1] This was shortly after grape production became an extensive industry in the State. In 1881 the insect is recorded as having been especially destructive on the islands in Lake Erie.[1] Injury in Ohio was extensive again in 1905 and 1906, but later decreased and in 1909 and 1910 the berry moth caused comparatively little damage [1, 2]. The infestation became severe again in 1913 and 1914 and reached its height in 1915, when in some local sections as much as two-thirds of the entire crop was ruined. The infestation continued high in 1916, the first season of the investigations here reported, and was but slightly less in 1917. Due to a cold autumn, however, the commercial damage was much less in 1917 than in any one of the four years preceding. In 1918, the last year of these investigations, the infestation about Cleveland was of no commercial importance, but in the section about Sandusky the loss was heavy in many unsprayed Catawba vineyards.

NORTHERN OHIO CONDITIONS AFFECTING INFESTATION.

The grape-berry moth has been a more general pest in the northern Ohio section than in the commercial grape sections of New York, Pennsylvania, or Michigan. This statement is based on published reports [3, 4] and on observations made by the senior author during the seasons of 1914–1918 inclusive.

Four principal factors have brought about this condition: The varieties grown, the cultural practices, the method of harvest, and the training system.

VARIETIES GROWN.

The Catawba variety predominates in the grape section about Sandusky and on the neighboring Lake Erie islands. Due to its late harvest this variety offers ideal conditions for the second-brood larvæ to mature and to reach winter quarters. In all the experimental work conducted the Catawba variety has been uniformly infested more heavily than the Concord, which is the predominating variety in the Chautauqua-Erie belt of Pennsylvania and New York and in Michigan sections.

CULTURAL PRACTICES.

Late in the fall, after grape harvest, a majority of the vineyards are "plowed on." This operation consists in beginning next to the

[1] Goodwin, W. H. The grape-berry worm (*Polychrosis viteana* Clemens). Ohio Agr. Exp. Sta. Bul. 293, p. 259–307 (20 pl. on p. 288–307). 1916.

[2] Gossard, H. A., and Houser, J. S. The grape-berry worm. Ohio Agr. Exp. Sta. Circ. 63. 16 p., fig. 1906.

[3] Johnson, Fred, and Hammar, A. G. The grape-berry moth. U. S. Dept. Agr. Bur. Ent. Bul. 116, Pt. II, p. 15–71, fig. 4–22, pl. 4–8. 1912.

[4] Isely, Dwight. Control of the grape-berry moth in the Erie-Chautauqua grape belt. U. S. Dept. Agr. Bul. 550. 44 p., 9 fig., 6 pl. 1917.

vines and plowing three successive furrows of soil toward the vines. Thus all leaves and trash in the vineyard are covered with from 3 to 5 inches of soil and ideal winter protection is afforded the hibernating pupæ which are in cocoons in the old grape leaves (Pl. II, fig. 2). In the spring before time for moth emergence this soil is worked away from the vines. In the Sandusky region it is plowed away and in grape sections near Cleveland it is removed with a disk or worked away with a shovel cultivator. This cultivation breaks the crust formed in the winter and in many cases turns to the surface the pupæ (Pl. I, fig. 3) that were plowed under the previous fall. This practice of covering the pupæ for the winter and then uncovering them early in the spring protects them from the extreme winter and allows the moths to emerge in the spring.

Pupæ of the berry moth, kept in the insectary yard at Sandusky under conditions similar to those described for the vineyards, lived through the winters of 1916–17 and 1917–18. In the spring of 1917 the emergence was 20 per cent and in 1918, after an unusually severe winter, it was 26 per cent. Comparative data are not at hand for the same winters with pupæ exposed as they would be in a vineyard plowed before grape harvest and then left until spring. In experimental work reported by Isely,[1] however, it was found that subsequent emergence from cocoons left through the winter of 1915–16 under exposed conditions in the vineyard was but 5 per cent as compared with 30 per cent emergence where the cocoons were covered by 2 inches of earth and then uncovered before time for emergence in the spring.

Since late plowing away in the spring is objectionable in northern Ohio from a horticultural standpoint, the writers recommend that when cultivation is completed in July the vineyards, whenever possible, be placed in final cultural condition for the winter and then that they be left in that condition until the next spring. The only objection to this practice is the excessive growth of weeds, which interferes with harvesting. This can be overcome by seeding a cover crop at the completion of cultivation.

METHOD OF HARVEST.

A large part of all the grapes in these sections and practically all of the Catawba variety were formerly sold for wine making. Since no particular packing is required for this market, all sorting is done in the vineyards by the pickers. Wormy berries are cut or shaken out of the clusters and allowed to fall to the ground and to remain in the vineyard. It appears that any other method of disposing of the infested grapes would be more costly in labor than would be warranted now that satisfactory control may be secured by spraying.

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[1] Isely, Dwight, op. cit.

TRAINING SYSTEM.

The "fan" system of grape training (Pl. III, fig. 1) which is used consistently in northern Ohio with the Catawba variety and a modification of which is used with Concords, is not generally practiced in any of the other commercial grape sections of the country.

This "fan" system consists in securing the bearing canes from the old vine head between the ground and the first wire and tying them up obliquely to the first and second wires, forming a V open at the top. Although two canes are the rule with the Catawba variety, when the thrift of the vine allows of more than two the additional canes are also carried up obliquely, completing the fan from which the system takes its name. As the young shoots bearing the clusters grow to a sufficient length they are tied up vertically to the middle and top wires. An effort is made to have these shoots spread, but to economize labor in tying they are often bunched 2 to 4 in a place. This system of training spreads the grape clusters all through the vine from the ground to the top wire and covers them almost completely with foliage and shoots (Pl. III, fig. 2). These conditions explain in part the failure to cover the grape clusters when any set-nozzle method of spraying is used, particularly when the spraying is done late in the season and considerable vine growth has been attained.

VARIETAL INFESTATION.

Several commercial varieties of grapes are present in northern Ohio, affording opportunity for observation on the relative infestation of the different varieties by the grape-berry moth. A list of varieties observed, beginning with the most heavily infested and ending with the least, is as follows: Shride, Elvira, Clinton, Reisling, Catawba, Norton, Niagara, Delaware, Agawam, Ives, Concord, Worden, and Moores Early.

In general it seems that the early-blooming varieties like the Shride and Clinton become heavily infested with the first-brood larvæ, and late-harvested varieties like Catawbas and Nortons become heavily infested with second-brood larvæ.

SEASONAL HISTORY.

The grape-berry moth completes one life cycle and a part of another each season. This insect is injurious only in the larval stage. There are two broods of worms or larvæ every season (Pl. I, fig. 1), the second much more numerous and destructive than the first (Pl. II, fig. 1). Since an understanding of the main points in the life history of the insect is necessary for the best application of control methods, a brief summary will be given.

The winter is spent in the pupal stage in cocoons (Pl. I, fig. 2) which the larvæ spin in grape leaves the previous fall. These leaves are the ones that fall early and become soft and sodden on the ground (Pl. II, fig. 2) and remain under the trellis during the winter. In the spring, previous to and during grape bloom, moths (Pl. I, figs. 4, 5) begin to emerge from the overwintering pupæ. This emergence gradually increases and continues at a high point for about 3 weeks. The moths begin to deposit eggs on the young grapes about 4 days after emergence and the eggs hatch in from 4 to 6 days. This first brood of larvæ or worms usually is not seriously destructive, though first-brood infestation amounting to as much as 30 to 35 per cent has been observed. The average length of the feeding period of this brood of larvæ is 23 days. When mature the larvæ migrate to grape leaves on the vines and spin their cocoons on them. From the cocoons moths emerge in about 13 days and begin laying eggs about 4 days later. The eggs of this second brood are placed on the nearly full-grown grapes and are easily found where the infestation is heavy. Before the eggs hatch they appear as creamy-white raised dots on the green grape berries, but after the larvæ leave the eggs the egg-shells appear as glistening white spots. This brood of eggs hatches in from 4 to 6 days and it is the resultant brood of larvæ that, if allowed to develop, does the greatest damage to the grape crop. (Pl. II, fig. 1.) The larvæ of this brood feed for a long period and usually leave the grapes just before harvest. They spin down to the ground and make their winter cocoons on old decayed grape leaves under the trellis. In the case of a cold fall many larvæ do not leave the grapes but are harvested with the grape crop. This condition prevailed in the fall of 1917 to an unusual degree and the result was a lighter infestation in 1918.

RELATION BETWEEN SEASONAL-HISTORY DATA AND CONTROL MEASURES.

The control experiments recorded in this bulletin are based on extensive field observations and on life-history studies conducted each season. The data shown in diagram form in figure 1 are summarized from the complete seasonal-history data. In determining the hatching periods of the larvæ 4 days are allowed from the emergence of the moths to the deposition of eggs and 6 days for incubation of the eggs. These are average figures from many observations extending over several seasons.

It is seen in figure 1 that in 1916 and 1917 a few larvæ had hatched before Concord grapes began to bloom and in 1918 that the dates of first hatching and beginning of bloom are coincident. In each season the first-brood larvæ were hatching in large numbers for about

3 weeks. It is important to note that the rise in the early part of the hatching is abrupt and the subsidence of hatching more gradual.

It has been the opinion of other writers that the largest part of the second-brood larvæ hatch within a shorter period of time than the first brood. The rearing records here illustrated do not support that belief but show the hatching periods to be of about equal length.

NATURAL CONTROL OF FIRST-BROOD LARVÆ.

It was observed that the grape berries infested by first-brood larvæ dropped readily from the vines when touched. It was thought that if these infested berries dropped in any great numbers at any particular time some cultural method such as covering these berries with soil might aid in the control of the insect. To determine this

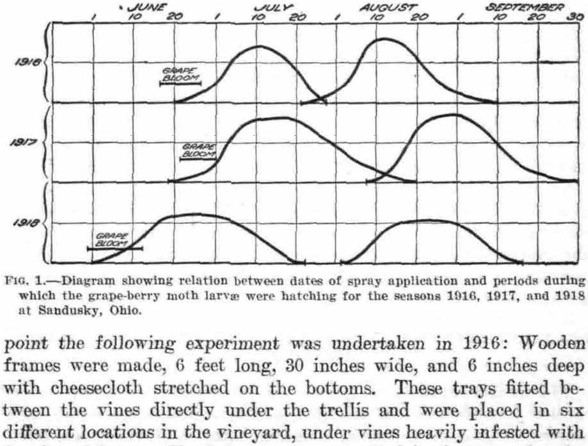

FIG. 1.—Diagram showing relation between dates of spray application and periods during which the grape-berry moth larvæ were hatching for the seasons 1916, 1917, and 1918 at Sandusky, Ohio.

point the following experiment was undertaken in 1916: Wooden frames were made, 6 feet long, 30 inches wide, and 6 inches deep with cheesecloth stretched on the bottoms. These trays fitted between the vines directly under the trellis and were placed in six different locations in the vineyard, under vines heavily infested with first-brood larvæ. Fresh leaves were supplied in the trays for the cocooning of any larvæ that might drop. The trays were put in place July 5 when first-brood infestation was about at its height and were left until August 15, when practically all first-brood larvæ had left the grapes. These trays were examined every three days. Practically no grapes dropped from the vines and not a single larva was taken throughout that period. From these negative results it is concluded that practically no natural control occurs from the dropping of grapes infested by first-brood larvæ.

CONTROL EXPERIMENTS.

STATUS OF SPRAY PRACTICE FOR GRAPE-BERRY MOTH CONTROL.

When these investigations were undertaken the following principal facts were known about spraying for the control of the grape-berry moth: First, satisfactory control had not been effected by the use of any system of set-nozzle spraying, particularly in thrifty vineyards where foliage growth was heavy. Second, satisfactory control had been effected in Ohio[1] by using the trailer method of spraying at the time of the hatchings of second-brood larvæ, usually in early August. This practice, however, left a heavy residue of spray material on the fruit at harvest time, which tended to exclude such fruit from a basket market. Third, two spray applications by the trailer method, the last when the grapes first touched in the clusters, had given satisfactory control on the Concord variety in the Chautauqua-Erie belt in 1915. This practice was to be thoroughly tried in northern Ohio on Concords and Catawbas.

SCOPE OF EXPERIMENTS.

From this summary of the knowledge available it appeared that the investigations should deal with three main points: (1) Time and number of spray applications, (2) chemicals used in spray materials, (3) spray residues left at harvest time.

In studying these factors spraying experiments were conducted by the writers in 6 vineyards in 1916, in 9 in 1917, and in 15 in 1918, a total of 30 vineyards. These vineyards were selected for the opportunity they offered for the advantageous study of any one or more of the important features enumerated above. Since little would be gained by considering each vineyard separately it has seemed desirable to assemble in Tables I, II, and III the data relating to the different vineyards and to bring together in similar form in Table IV the results of the experiments.

TIME OF SPRAY APPLICATIONS.

Former experiments[2] indicated that a spray application directly after grape blooming was important for the control of both grape rootworm beetles and grape-berry moth larvæ. In the Sandusky and island sections of Ohio a spray application following grape bloom is usually made for the control of downy mildew, *Plasmophora viticola*, particularly on Catawba and Delaware varieties. This application directly following grape bloom was considered as the first spray in all of the experiments in which it was included. The second spray

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[1] Goodwin, W. H., op. cit.

[2] Goodwin, W. H., op. cit. Johnson, Fred, and Hammer, A. G., op. cit. Isely, Dwight, op. cit.

was applied when the grapes touched in the clusters, but before the clusters were tight enough to prevent the spray material from being driven between the grapes. This stage of grape growth usually occurs from 3 to 4 weeks after bloom. This second spraying was designed to kill the late hatching first-brood larvæ and to remain on the grapes to be effective when the second-brood larvæ hatched. The third spraying was timed in each case to precede immediately the hatching period of the majority of second-brood larvæ.

METHOD OF APPLICATION.

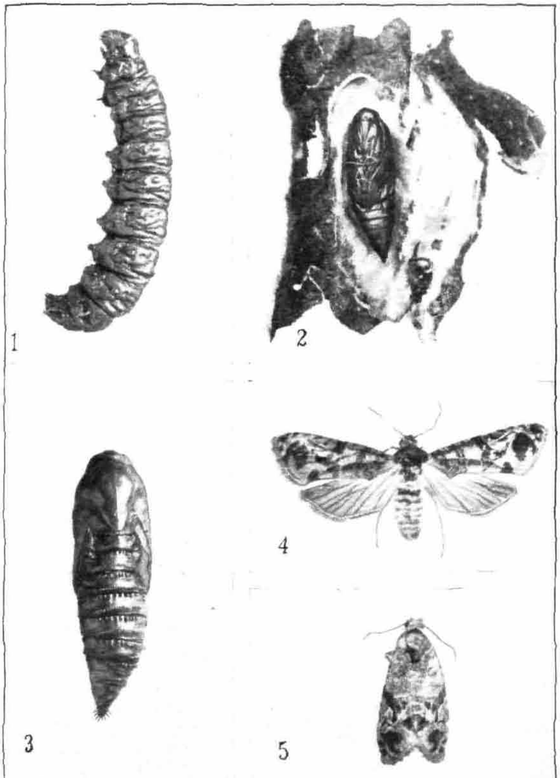
All spraying was done by the hand or trailer method in which 2 hose lines of from 20 to 50 feet trail behind the sprayer, and the spray material is delivered through short spray rods and angle nozzles, directed by hand as in tree spraying. Variations in this method will be discussed later. Sufficient pressure was maintained to drive the spray well into the clusters, but the amount of pressure varied from 125 to 225 pounds in different vineyards. The best pressure to maintain will vary somewhat with the vineyards, but the writers believe that from 175 to 225 pounds usually will be found most efficient. Nozzles set at an angle are absolutely necessary for efficient work, and it was found that nozzles set at angles of 45° allowed more freedom of handling than those set at 90°. A nozzle aperture of $\frac{1}{16}$-inch was most commonly used, but the most efficient size was found to vary with the vineyard and other local conditions.

WEATHER CONDITIONS[1] AFFECTING SPRAY RESULTS.

The season of 1916 was about normal in all respects except for an unusually dry period during July and August which was favorable for spraying and for spray material adhering. These same conditions were likewise favorable for the development of an unusually large second brood of worms. September and October were warm and dry, conditions also favorable to extensive berry moth injury as shown in the uniformly heavy infestation in the checks (Table IV).

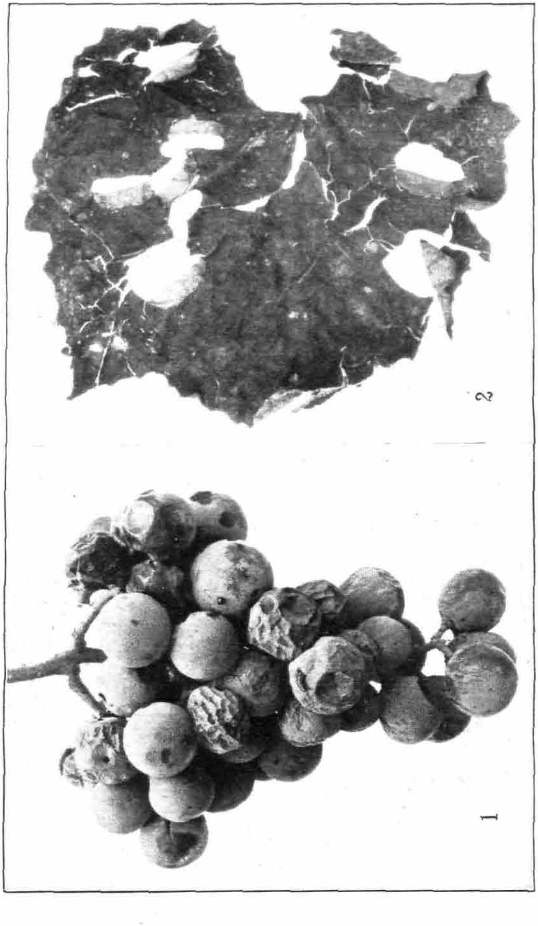
In 1917 conditions were decidedly unfavorable for spraying operations. Both the first and second applications were interfered with by rain and closely followed by showers of varying intensities. In July the total rainfall was but 0.46 inch, but this came between the first and second spray applications. The maturing of first-brood larvæ was favored by an exceedingly hot and dry period from July 28 to August 6 and a subsequent heavy hatching of second-brood larvæ followed. September was 3.3° below normal in temperature and slightly below in precipitation, while October was 8.3° below normal with 3.79 inches of rainfall above normal. These unfavorable

[1] Weather records from the U. S. Weather Bureau Station at Sandusky, Ohio.



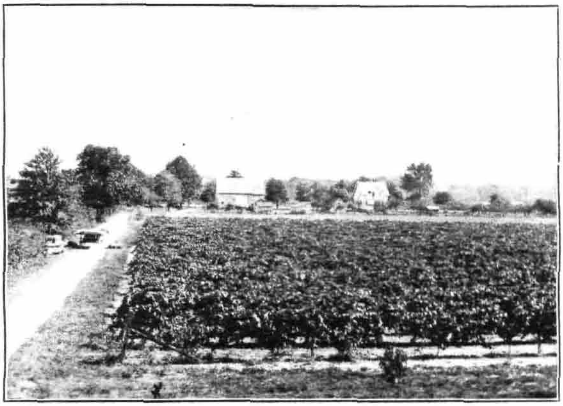
THE GRAPE-BERRY MOTH (POLYCHROSIS VITEANA).

FIG. 1.—Larva. FIG. 2.—Pupa (ventral aspect) in cocoon. FIG. 3.—Pupa (dorsal aspect). FIGS. 4, 5.—Adult. All greatly enlarged.



DAMAGE BY THE GRAPE-BERRY MOTH.

FIG. 1.—Grape cluster at harvest time, heavily infested with second-brood grape-berry moth larvæ. FIG. 2.—Cocoons in sodden grape leaf under trellis.



THE "FAN" SYSTEM OF GRAPE TRAINING.

FIG. 1.—Northern Ohio vineyard trained according to the fan system. FIG. 2.—Grapevine showing fan system of training with grape clusters scattered from near the ground to the top wire.

conditions in September and October retarded the development of second-brood larvæ and counteracted the previous favorable conditions.

The season of 1918 opened unusually early and continued favorable for all growth processes throughout the season. Spraying was but little interfered with and no unusual weather conditions prevailed that affected the spraying results.

SPRAYING EXPERIMENTS IN 1916.

TABLE I.—*Vineyards used for spraying experiments in northern Ohio, 1916.*

Vineyard No.	Vineyard owner and location.	Varieties.	Dates of spray applications.			Estimated infestation 1915.	Gallons of spray material per acre.		
			First.	Second.	Third.		First.	Second.	Third.
						Per ct.			
1	Roland Brown, Kelleys Island.	Catawbas.	July 5	July 21	Aug. 9	70	173	192	192
2	O. W. Brown, Kelleys Island.	....do......	July 3	July 20	....do...	85	120	202	200
3	Charles Duggan, Put-in-Bay.	....do......	June 30	July 17	Aug. 7	75	112	176	112
4	W. R. Huntington, Put-in-Bay.	Catawbas, Concords.	July 1	July 19	Aug. 8	80	105	160	112
5	E. Manty, Venice.......	....do......	June 29	July 12	Aug. 3	90	128	304	150
6	John Schonhart, Venice.	....do......	June 27, 28.	July 11, 12.	Aug. 2	70	90	236	230

Experiments were conducted in six vineyards in the Sandusky and island sections, as shown in Table I. In all of these experiments the arsenicals were applied in Bordeaux either 3-3-50 or 2-3-50 strength. Laundry soap at the rate of 2 pounds to 50 gallons was used for the first spray application in all of the vineyards and for the second spray in vineyards Nos. 5 and 6. It became apparent during the second spray application that resin fish-oil soap possessed better spreading qualities than laundry soap and so it was used in all the other spray applications at the rate of 1 pound to 50 gallons. Previous to bloom all of the vineyards received an application of Bordeaux alone for the control of downy mildew. The strength of arsenicals in the berry-moth sprays was varied in the different vineyards as shown in Table VI.

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SPRAYING EXPERIMENTS IN 1917.

TABLE II.—*Vineyards used for spraying experiments in northern Ohio, 1917.*

Vineyard No.	Vineyard owner and location.	Varieties.	Dates of spray applications.			Estimated infestation 1916.	Control of grape-berry moth in 1916.	Gallons of spray material per acre. Spray applications.		
			First.	Second.	Third.			First.	Second.	Third.
						Per ct.				
1	Becker Wine Co., Kellys Island.	Catawbas.	July 14	Aug. 3, 4	....	25	(1)	150	193	......
2	O. W. Brown, Kelleys Island.	....do......	July 12	Aug. 2	....	50	(2)	165	178	......
3	Paul Cooley, Dover Center.	Concords..	July 12, 13.	July 26	Aug. 18	40	(3)	250	300	300
4	Fred Foye, Put-in-Bay.	Catawbas.	July 11, 12.	July 31, Aug. 1.	....	90	(3)	150	233	......
5	George Lewis, Bay Village.	Concords, Ives.	July 5-9	July 23-26.	Aug. 17	40	(3)	200	275	200
6	John Schonhart, Venice.	Catawbas, Concords.	July 3, 4	July 20-25.	Aug. 14	20	(4)	150	312	280
7	T. W. Wearsch, Avon Lake.	Concords, Ives.	July 10	July 27	Aug. 17	90	(3)	120	160	160

[1] One spray with trailers.
[2] Two sprays with trailers but operators riding.
[3] No spray.
[4] Two sprays with trailers.

As seen in Table II the experiments were conducted in seven vineyards, four in the Sandusky and island sections and three in the Dover and Avon sections just west of Cleveland, Ohio. The experiments were so placed as to include local variations in the different grape sections, such as weather, cultural practices, varieties, and markets. All the arsenicals were applied in Bordeaux 2–3–50 with resin fish-oil soap added at the rate of 1 pound to 50 gallons. The following single exception was made: In vineyard No. 5 copper sulphate was omitted from the third spray application and laundry soap, 2 pounds to 50 gallons, was substituted for resin fish-oil soap.

SPRAYING EXPERIMENTS IN 1918.

TABLE III.—*Vineyards used for spraying experiments in Northern Ohio, 1918.*

Vineyard No.	Vineyard owner and location.	Varieties.	Date sof spray applications.			Estimated infestation 1917.	Control of grape-berry moth in 1917.	Gallons of spray material per acre. Spray applications.		
			First.	Second.	Third.			First.	Second.	Third.
						Per ct.				
1	C. D. Powell, Vermilion.	Ives.......	June 13, 14.	July 9	Aug. 5	15	(1)	(2)	(2)	(2)
2	O. W. Brown, Kelleys Island.	Catawbas.	June 29	July 18	....	15	(1)	(2)	(2)	(2)
3	T. W. Wearsch, Avon Lake.	Concords, Ives.	June 14, 15.	July 11, 12.	....	2	(1)	100	150	......
4	Ernest Dunning, Avon Lake.	Concords..	June 19	July 16	....	50	(3)	200	342	......
5	V. Doller, Put-in-Bay.	Catawbas.	July 2-3	Omitted.	....	75	(3)	(2)	(2)	......

[1] Two sprays with trailers. [2] No record. [3] No spray.

The experiments were extended in 1918 to include work in 15 vineyards, but as infestation was not sufficiently heavy for satisfactory comparisons in all the vineyards only the 5 showing the heaviest infestations are included in Tables III and IV.

The arsenicals were applied in Bordeaux 2–2–50 in vineyards Nos. 1, 2, and 5. In vineyards Nos. 3 and 4 copper sulphate was omitted at the request of the owners. Stone lime 2 pounds to 50 gallons was retained to care for any free arsenic in the arsenicals. Resin fish-oil soap at the rate of 1 pound to 50 gallons was used uniformly throughout the experiments.

METHOD OF RECORDING RESULTS OF SPRAYING EXPERIMENTS.

It had been learned in earlier work [1] that results based on weights of harvested fruit were misleading, owing to the varying thrift of vineyards, time of harvest, weather conditions affecting the development of worms, etc. The weight method, therefore, was abandoned in favor of the count method. This consists in selecting a representative number of vines in each sprayed plat and in each check, harvesting all the fruit from these vines, counting the clusters, then the clusters containing wormy berries, then removing the wormy grapes and counting them. To ascertain the average number of grapes per cluster, 100 representative clusters were taken in each vineyard and all the grapes counted. The number of clusters in each plat was then multiplied by the average number of grapes per cluster to give the total number of grapes examined in each plat.

In all control work on the grape-berry moth, the unevenness of infestation within a vineyard has made experimental results difficult to interpret. This uneven infestation prevailed throughout these investigations but was cared for whenever possible by placing checks across the control plats and reading the results on the control plat the second post-length away from the checks. While the plan does not entirely overcome the difficulty, the writers feel that the averages from several vineyards closely approximate actual conditions.

In all cases the fruit from at least 10 vines was examined and when possible the examinations included all the fruit from 20 to 25 vines. Exceptions to this occurred only when there were less than 10 vines of a particular variety in a plat. First-brood counts were made in some instances, but since they add little to the final results they are omitted from the tables.

[1] Johnson, Fred, and Hammar, A. G., op. cit.; Isely, Dwight, op. cit.

SUMMARY OF RESULTS BY VINEYARDS, TIME AND NUMBER OF SPRAY APPLICATIONS, 1916, 1917, 1918.

TABLE IV.—*Summary by vineyards of spraying results for control of the grape-berry moth, Sandusky, Ohio, seasons 1916, 1917, 1918.*

[All spray applications made by the hand or trailer method.]

SEASON 1916.

Spray mixture.			Combination of spray applications.			Varieties used.	Vineyard No. 1.		Vineyard No. 2.		Vineyard No. 3.		Vineyard No. 4.		Vineyard No. 5.		Vineyard No. 6.		Vineyard No. 7.		Averages of all vineyards.	
Number of applications.	Arsenate of lead powder.	Material.	First. 3 to 5 days after bloom falls.	Second. When grapes touch in the clusters.	Third. When second-brood larvæ begin to hatch.		Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
	Lbs.	Galls.																				
2	2½	50	X	X	...	Catawbas	31.59	98.26	28.29	63.50	6.28	78.75	...	...	22.74	94.99	10.41	64.39	...	...	19.86	79.98
						Concords	...	...	...	...	...	...	3.25	64.52	10.20	90.93	3.34	43.32	...	...	5.59	66.25
2	2½	50	X	...	X	Catawbas	33.54	98.26	...	...	8.27	78.75	...	...	...	...	15.17	77.93	...	...	18.99	83.98
						Concords	...	...	...	...	...	...	...	...	...	...	2.31	41.16	...	...	2.31	22.67
2	2½	50	...	X	X	Catawbas	...	...	...	...	7.67	78.75	1.37	81.12	...	...	8.31	77.93	...	...	5.78	79.27
						Concords	...	...	...	...	...	...	...	...	...	...	2.66	22.67	...	...	2.66	22.67
2	1½	50	X	X	...	Catawbas	...	...	...	...	...	...	.93	81.12	...	...	11.90	70.26	...	...	6.41	75.69
						Concords	...	...	...	...	...	...	...	...	...	...	5.56	52.83	...	...	5.56	52.83
3	2½	50	X	X	X	Catawbas	16.96	98.26	9.06	63.50	3.62	78.75	...	...	2.48	94.99	2.18	64.39	...	...	6.86	79.98
						Concords	...	...	...	...	...	...	2.26	64.52	1.48	90.93	.21	43.32	...	...	1.32	66.26
3	1½ 2½	50 50	X, 1½ lbs.	X, 1½ lbs.	X, 2½ lbs.	Catawbas	...	...	...	...	...	...	.81	81.12	...	...	...	...	...	...	.81	81.12
1	2½	50	...	X	...	Catawbas	...	...	...	...	13.30	78.75	2.37	81.12	...	...	22.78	74.24	...	...	12.82	78.04
						Concords	...	...	...	...	...	...	...	...	...	...	11.48	33.68	...	...	11.48	33.68
SEASON 1917.																						
2	2½	50	X	X	...	Catawbas	0.67	64.09	6.47	79.31	...	...	7.72	79.63	...	...	...	...	...	...	4.95	74.34
						Concords	...	...	...	...	...	...	...	...	...	...	0.48	30.14	...	...	.48	30.14
						Ives	...	...	...	...	...	...	...	...	...	...	2.11	39.67	...	...	2.11	39.67

2	1½	50	X	X		Catawbas	2.03	64.09	8.86	78.17			5.84	63.03			1.48	42.00			4.55	61.82
						Concords					.47	61.61			.84	32.11	.18	20.60	2.66	88.03	1.04	50.57
						Ives									.43	20.14	2.94	19.59			1.68	19.86
2	1½	50	X		X	Concords					.83	46.52					1.40	24.77			1.11	35.64
						Ives									1.64	20.14	.85	39.67	2.55	88.03	1.68	49.28
3	1½	50	X	X	X	Catawbas											.41	42.00			.41	42.00
						Concords					1.16	61.61			.42	32.11	.60	30.09	2.66	88.03	1.21	52.96
						Ives											1.67	19.59			1.67	19.59
2	1½ 2½	50 50	X, 1½ lbs.	X, 2½ lbs.		Catawbas	.95	64.09	20.11	82.25			4.49	63.03			.54	32.92			6.52	60.57
						Concords											.70	32.68			.70	32.68
1	2½	50		X		Catawabs			28.07	83.36			13.87	79.63							20.97	81.49
						Concords											.94	30.14			.94	30.14
						Ives											7.23	39.67			7.23	39.67
1	1½	50	X			Concords					20.64	46.52									20.64	46.52

SEASON 1918.

2	1½	50	X	X		Catawbas			4.78	68.02											4.78	68.02
						Concords					0.41	2.54	1.00	6.28							.71	4.41
						Ives	0.86	7.85													.86	7.85
2	1½	50	X		X	Ives	2.46	11.00													2.46	11.00
3	1½	50	X	X	X	Ives	.95	16.24													.95	16.24
2	1	50	X	X		Catawbas			7.39	62.36											7.39	62.36
						Ives	2.08	6.93													2.08	6.93
1	1½	50		X		Catawbas			25.67	82.82											25.67	82.82
						Ives	4.20	10.04													4.20	10.04
1	1½	50	X			Catawbas									5.09	17.19					5.09	17.19
						Concords							5.95	6.28	6.27	21.37					6.11	13.83
						Ives					8.75	9.89									8.75	9.89

In Table IV are brought together all of the data bearing on the time and number of spray applications, arranged by vineyards and varieties. This table provides for a comparison of the plats within each vineyard by reading from top to bottom, as well as a comparison of the plats receiving similar spray treatment in the different vineyards, by reading across. While the comparison between plats within a vineyard is relatively consistent, considerable variations exist between vineyards. A study of the column of averages shows satisfactory commercial control to have been effected in all plats which received either two or three spray applications with the exceptions of the first two plats. These two plats illustrate the necessity of timeliness of spraying and adhesiveness of spray material, since in 1917 the more timely spray treatment, and the use of resin fish-oil soap throughout, reduced the average infestation from 19 per cent in 1916 to 5 per cent in 1917.

RELATIVE EFFICIENCY OF DIFFERENT TIMES AND NUMBERS OF SPRAY APPLICATIONS.

TABLE V.—*Summarized results from Table IV—relative efficiency of different times and numbers of spray applications, 1916, 1917, and 1918—Arsenicals applied in Bordeaux mixture and soap solution.*

Number of applications.	First, 3 to 5 days after bloom.	Second, when grape berries touch in cluster.	Third, when second-brood larvæ begin to hatch.	Arsenate of lead powder, pounds to 50 gallons material.	Years tried.	Number of vineyards.	Number of plats.	Percentage of grape berries infested, averages of all experiments, 1916, 1917, 1918.					
								Catawbas.		Concords.		Ives.	
								Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
2	X	X	......	2½	1916, 1917	9	11	11.35	79.22	3.04	48.20	2.11	39.67
2	X	......	X	2½	1916	3	4	18.99	83.98	2.31	22.67	......	......
2	X	X	......	1½	1917, 1918	11	14	4.67	64.92	.82	26.00	1.53	16.85
2	X	......	X	1½	1917, 1918	5	6	......	......	1.11	35.64	2.07	30.14
2	......	X	X	2½	1916	3	4	5.78	79.27	2.66	22.67	......	......
3	X	X	X	2½	1916	6	8	6.86	79.98	1.32	66.26	......	......
3	X	X	X	1½	1917, 1918	5	5	.41	42.00	1.21	52.96	1.31	17.92
1	......	X	......	2½	1916, 1917	6	7	16.90	79.77	6.21	31.91	7.23	39.67
1	X	......	......	1½	1917, 1918	4	4	......	......	13.30	26.40	8.75	9.89
2	X	X	......	1	1918	2	2	7.39	62.36	......	......	2.08	6.93
1	......	X	......	1½	1918	2	2	25.67	82.82	......	......	4.20	10.04

A comparison of the combinations of the first and second sprays with first and third sprays shows little choice between them as far as berry-moth control is concerned. Since the combination of the first and second sprays leaves the fruit practically free of all spray residue at harvest time and since the second spray is more easily applied than the third because of lighter grape foliage, this combination of the first and second application is preferred by the writers. It is important to know, however, that if for any reason the second spray can not be made, the third may be applied and will give about

equally as good control. When the third application is made the fruit will usually be unfit for basket market because of excessive spray residue.

Where a third application is added to the first and second, control is slightly better, 6.8 per cent infestation as compared with 11.3 per cent in 1916 and 0.4 per cent as compared with 4.6 per cent, an average for 1917 and 1918. These differences, however, were not sufficient to justify the expense of the third application.

ONE-SPRAY METHOD.

One spray application by the trailer method at the time the grapes first touched in the clusters gave an average control of 83 per cent on Catawbas and 94 per cent on Concords as compared with 89 per cent control on Catawbas and 97 per cent on Concords when both the first and second sprays were given. This is a good showing for a "one-spray" schedule and this treatment might be the most efficient under some conditions. All results indicate that this one spray may be depended upon to save the crop from ruin by the berry moth.

In an effort to eliminate entirely the factor of spray residue on fruit for the basket market the spray application directly after grape bloom was tried alone. Data are insufficient on this treatment but indicate a marked effect on the final infestation. This treatment has the advantages of being the most important one for rootworm beetle control and of being timely to prevent black-rot infection of the young grapes. It may develop that this method will be practical after the infestation of the moth has been reduced by the use of the two-spray schedule for one or more years. Experiments on this point were conducted in several vineyards in 1918 but adjacent checks failed to show sufficient infestation to make results conclusive.

CONCLUSIONS FROM EXPERIMENTS.

The combinations of the first spray treatment with the second and of the first with the third gave satisfactory control. The third spray added to the first and second increased the effectiveness, but not enough to justify the expense of making the application. The second application alone averaged 83 per cent control and in all cases saved the commercial crop. The first application alone reduced the final infestation appreciably but needs further testing.

MATERIALS USED IN SPRAYS.

ARSENICALS.

ARSENATE OF LEAD, COMMERCIAL POWDER.

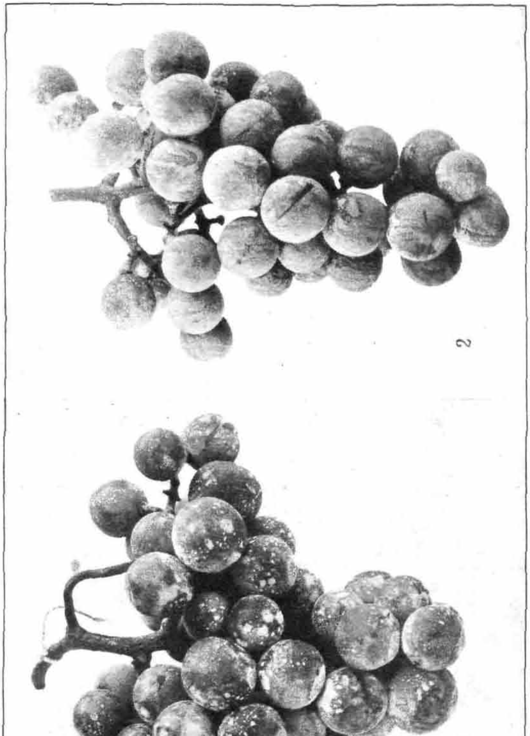
Arsenate of lead in powder form was used throughout this work. Since previous infestation had been extremely heavy in the experimental vineyards, the powder was used in 1916 at the rate of 2½

pounds to 50 gallons, equivalent to 5 pounds of paste to 50 gallons, as a basis for comparison that year. The 1½-pound rate was used in but two vineyards in 1916. In 1917 the 2½-pound rate was retained in four vineyards and the 1½-pound used in seven. In 1918 comparison was made between 1 pound and 1½ pounds of arsenate of lead powder.

TABLE VI.—*Relative efficiency of arsenate of lead at the rate of 1, 1½, and 2½ pounds (powder) to 50 gallons liquid.*[1]

Pounds of arsenate lead powder to 50 gallons liquid	Spray applications.		Number of vineyards.	Number of plats.	Vineyard No.	Percentage of infested grape berries.					
						Catawba variety.		Concord variety.		Ives variety.	
	3 to 5 days after grape bloom.	When grapes touch in clusters.				Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
SEASON 1916.											
1½	X	X	2	3	4	0.93	81.12				
	X	X			6	11.90	70.26	5.56	52.83		
Averages			2	3		6.42	75.69	5.56	52.83		
2½	X	X	2	3	4			3.25	64.52		
	X	X			6	10.41	64.39	3.34	43.32		
Averages			2	3		10.41	64.39	3.30	53.92		
SEASON 1917.											
1½	X	X			1	2.03	64.09				
	X	X			2	8.86	78.17				
	X	X			3			0.47	61.61		
	X	X			4	5.84	63.03				
	X	X			5			.84	32.11	0.43	20.14
	X	X			6	1.48	42.00	.18	20.60	2.94	19.59
	X	X			7			2.66	88.03		
Averages			7	10		4.55	61.82	1.04	50.59	1.68	19.86
2½	X	X			1	.67	64.09				
	X	X			2	6.47	79.31				
	X	X			4	7.72	79.63				
	X	X			6			.48	30.14	2.11	39.67
Averages			4	5		4.95	74.34	.48	30.14	2.11	39.67
SEASON 1918.											
1½	X	X			1					0.86	7.85
	X	X			2	4.78	68.02				
	X	X			3			0.41	2.54		
	X	X			4			1.00	6.28		
Averages			4	4		4.78	68.02	.71	4.41	.86	7.85
1	X	X			1					2.08	6.93
	X	X			2	7.39	62.36				
Averages			2	2		7.39	62.36			2.08	6.93

[1] All plats received Bordeaux 2-3-50 and resin soap 1 pound to 50 gallons in 1917 and 1918. Same in 1916, except laundry soap 2 pounds to 50 gallons, first application; and second application vineyards Nos. 5 and 6.



SPRAYING AGAINST THE GRAPE-BERRY MOTH.

Comparative spreading qualities in spray mixture of a laundry soap (fig. 1) and a resin fish-oil soap (fig. 2).

The differences in the control effected by the various strengths of arsenate of lead were slight, as shown in Table VI. When comparing the averages the differences in the infestation of the adjoining checks should be kept in mind. The tests of 1 pound to 50 gallons have not been sufficient to justify one in drawing conclusions, but 1½ pounds to 50 gallons has proved adequate for control.

ARSENATE OF CALCIUM, COMMERCIAL POWDER.

Much interest has centered in the comparative merits of arsenate of calcium and arsenate of lead as insecticides. Arsenate of calcium has the advantage of being much cheaper than arsenate of lead, but doubt has prevailed as to its adhesive qualities and its effect on foliage. Since an extra spreader and adhesive in the form of resin soap is necessary even with arsenate of lead for spraying grape clusters, and since grape foliage is comparatively hardy to arsenicals, it was thought that arsenate of calcium should have a wide use in grape spraying.

TABLE VII.—*Relative efficiency of commercial arsenate of calcium and arsenate of lead for control of the grape-berry moth, Sandusky, Ohio, 1917, 1918. Both arsenicals applied in Bordeaux 2–3–50 with 1 pound of resin soap to each 50 gallons.*

Arsenical, pounds to 50 gallons.	Spray applications.		Number of vineyards.	Number of plats.	Vineyard No.	Percentage of infested grape berries.					
						Catawba variety.		Concord variety.		Ives variety.	
	3 to 5 days after grape bloom.	When grapes touch in clusters.				Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
					1917.						
					1	9.46	64.09	......	......	......	......
					4	13.78	79.63	......	......	......	......
					5	......	......	0.58	32.11	......	......
Arsenate of calcium commercial powder, 42 per cent As_2O_5, 1 pound to 50 gallons..........	X	X	......	......	6	......	......	.66	40.60	1.28	39.67
					1918.						
					1	......	......	......	......	1.04	6.23
					2	7.22	87.06	......	......	......	......
Averages..........	......	......	6	7	......	10.15	76.93	.62	36.35	1.16	22.95
					1917.						
					1	2.03	64.09	......	......	......	......
					4	5.84	63.03	......	......	......	......
					5	......	......	.84	32.11	......	......
Arsenate of lead commercial powder, 30 per per cent As_2O_5........	X	X	......	......	6	......	......	.18	20.60	2.94	19.59
					1918.						
					1	......	......	......	......	.86	7.85
					2	4.78	68.02	......	......	......	......
Averages..........	......	......	6	7	......	4.22	65.05	.51	26.35	1.90	13.72

Table VII shows the comparison of arsenate of calcium with arsenate of lead in six vineyards and seven plats. Control was

almost complete for both materials on the Ives and Concord varieties. On the Catawbas the arsenate of calcium averaged 90 per cent control and the arsenate of lead 96 per cent, but the checks adjacent to the arsenate of calcium plats were 12 per cent more heavily infested than those adjacent to the arsenate of lead plats so the comparisons are very close. These results may indicate that the arsenate of lead adhered slightly longer in the season than the arsenate of calcium. In recording the spray residue on the fruit at harvest time, slightly less was found on the arsenate of calcium plats than on corresponding arsenate of lead plats. This feature is an advantage in grape-berry moth spraying and is discussed later. No foliage injury that could be attributed to the arsenical occurred on any of the arsenate of calcium plats.

Grape spraying experiments were continued in 1919 and foliage injury occurred on all plats of the Ives variety where commercial arsenate of calcium was used at the rate of 1½ pounds to 50 gallons of water with 3 pounds of freshly burned stone lime slaked and added to each 50 gallons of spray solution. This experience indicates that the use of arsenate of calcium on the Ives variety is unsafe.

ARSENATE OF CALCIUM, HOME-MADE PASTE.

Varied success had been reported from the use of home-made arsenate of calcium pastes as sprays for fruit trees. To determine the efficiency of these home-made materials for use in sprays on grapes the following experiments were conducted. Pastes were made according to the following formulas and methods and applied in spray solutions to grapes:

(1) Arsenate of soda + stone lime.

Sodium arsenate, fused (dry powdered) 60 per cent As_2O_5	ounces	30
Stone lime	do	18
Water	do	48
Total	do	96

The sodium arsenate was dissolved in the water and the resultant solution used to slake the lime. A smooth paste arsenate of calcium of about 18 per cent As_2O_5 content resulted. This was decanted 5 times to remove the sodium hydroxid. The resultant paste was used at the rate of 2½ pounds to 50 gallons to be comparable with arsenate of lead (commercial powder 30 per cent As_2O_5), 1½ pounds to 50 gallons.

(2) Arsenic acid + stone lime.

Arsenic acid (liquid) 78 per cent As_2O_5	ounces	10
Stone lime	do	8
Water	do	34
Total	do	52

The lime was slaked to a smooth paste with 18 ounces of water. The arsenic acid was diluted with the remaining 16 ounces of water and the diluted acid added to the lime paste a little at a time. The paste was stirred vigorously during the mixing. With each addition of acid the lime had a tendency to granulate, but continued stirring restored the smooth pasty condition. A sample of the final paste was analyzed by the United States Bureau of Chemistry under miscellaneous laboratory No. 24714 as follows:

Moisture	69.7
Total CaO (as received)	15.08
Total As_2O_5 (as received)	12.04
Water soluble As_2O_5	.02

5 grams samples in 1,000 c. c. CO_2 free water; equivalent to 2 pounds to 50 gallons. Free lime calculated as calcium hydroxid $Ca(OH)_2$ 4.4 per cent.

Paste made according to this formula was used on grapes in 1918 at the rate of 4 pounds to 50 gallons of water. Grape-berry moth infestation failed to develop in numbers sufficient for the desired comparisons in any one of the four vineyards in which these materials were used. The spreading qualities and effects on grape foliage, however, are important. The arsenicals were applied either in Bordeaux 2–2–50 or with stone lime 2 pounds to 50 gallons added to the mixture. In all cases resin fish-oil soap at the rate of 1 pound to 50 gallons was also added. The paste made from sodium arsenate spread equally as well as the commercial arsenate of calcium powder or arsenate of lead powder. The paste made from arsenic acid failed to spread as well and when dry it was not a smooth, even coating such as is desired. In no case could foliage injury be attributed directly to the use of either of the home-made arsenate of calcium pastes.

Spreaders and Adhesives.

Because of the partial failure of arsenate of lead and Bordeaux to spread over or "wet" the individual grapes in the grape clusters, various materials have been added to these to facilitate the spreading process.

The qualities desired in such a spreader are (1) quick-wetting power, (2) adhesive power when dry, and (3) that it be easily prepared for use. In addition, a material to be suitable must be compatible with Bordeaux mixture and arsenicals and also be comparatively cheap.

Former investigations[1] had shown that some form of soap was the most practical material for the purpose. When these investigations were undertaken various soaps were recommended by differ-

[1] Isely, Dwight, op. cit.

ent authorities. To determine the most efficient of these, experiments as shown in Table VIII were conducted in 1916.

TABLE VIII.—*Relative efficiency of different soaps as spreaders and adhesives, Schonhardt vineyard, Venice, Ohio, 1916.*

Kind of soap used.	Pounds in 50 gallons.	Spray materials combined with soaps.	Gallons spray material per plat second application.	Increase over resin soap.	Results in grape-berry moth control.				
					Number vines examined.	Number clusters examined.	Number grapes examined.	Infested grapes.	Variety.
				Per ct.				Per ct.	
Soft	2	(1)	140	86	14	790	18,960	17.04	Concords.
					10	342	12,996	24.83	Catawbas.
Laundry	2	(1)	100	33	11	608	14,592	6.78	Concords.
					10	198	7,524	6.11	Catawbas.
Resin fish-oil	1	(1)	75	0	12	735	17,640	8.50	Concords.
					10	311	11,918	8.37	Catawbas.
Checks					22	1,050	25,200	41.16	Concords.
					34	1,019	30,570	73.12	Catawbas.

[1] Bordeaux 3-3-50, arsenate of lead commercial powder 2½ pounds to 50 gallons.

Adjoining grape rows, each row including Concord and Catawba varieties, were sprayed three times during the season, the first application three to five days after grape bloom, June 27, the second when the grapes touched in the clusters, July 13, and the third at the beginning of the hatching period of second-brood larvæ, August 3. All spraying was done by the trailer method with medium disk angle nozzles and at a pressure of 150 pounds. The soaps were used as spreaders in mixtures of Bordeaux 3–3–50 and arsenate of lead powder 2½ pounds to 50 gallons. The season was unusually dry during July and August, favoring both adherence of spray materials and the development of the grape-berry moth. The Concords were harvested September 29 and the Catawbas October 10.

The soft soap used was a bulk product made especially for use in commercial laundries. This soap dissolved readily in hot water, but when applied to grapes formed in globules on the leaves and grape berries and dried in large drops. This condition was reflected in the percentages of infested grapes at harvest time, 17 per cent on Concords and 25 per cent on Catawbas. This increase in infestation on the Catawba variety did not occur with the laundry or resin soap, and so seems to indicate less adhesive power late in the season in the soft soap, since the Catawbas were harvested 12 days later than the Concords. The laundry soap used (Pl. IV, fig. 1) was the common yellow-bar soap, chipped and dissolved in hot water. This spread smoothly over the grape foliage and berries and gave a satisfactory covering when the spray was directed on the clusters for a sufficiently long time, but the amount required to "wet" them was 33 per cent greater than when the resin soap was used. When the third-spray application is used, as in this experiment, the adhesive

quality of the laundry soap appears equally as great as that of the resin. However, when the first and second sprays are applied and the third omitted, leaving a longer period between the last spray application and harvest time, it appears from field observations that the resin soap adheres longer than the laundry soap.

The resin fish-oil soap used was the commercial product obtained in bulk and of the consistency of thick molasses. This soap is readily dissolved in hot water and wets the clusters (Pl. IV, fig. 2) easily, as is indicated by the use of but 75 gallons as compared with 100 gallons of laundry soap solution and 140 of soft soap solution. The resin soap adhered the longest of any material tried. It was found that 1 pound of this soap to 50 gallons was about as efficient as 2 pounds of the other soaps and at the rate of 1 pound to 50 gallons is as cheap. No difference in compatibility with Bordeaux and arsenate of lead could be noted among the different soaps.

In conclusion it can be said that the resin fish-oil soap proved to have all the desired qualities of a spreader and adhesive and in the present state of knowledge appears the best spreader to use in grape spraying.[1]

COMBINATION SPRAYS.

In the Sandusky and Lake Erie island sections where the Catawba variety predominates it is desirable to combine a fungicide for control of downy mildew, *Plasmophora viticola*, with the arsenical and soap for rootworm beetle and grape-berry moth control. In the other sections it is sometimes desirable to use the same combination for blackrot and insect control.

Bordeaux, either 2–2–50, 2–3–50, or 3–3–50, was used in combination with arsenate of lead powder 1½ and 2½ pounds to 50 with soaps at the rate of 1 and 2 pounds to 50. In some of the experiments the copper sulphate was omitted and stone lime, 2 pounds to 50 gallons, was used. The combining of the insecticide with the fungicide appeared to make no difference in insect control.

In some cases slight burning of Concord and Catawba foliage and serious burning of Ives foliage resulted from application of the Bordeaux-arsenate of lead-soap combination. The burning was most noticeable during the abnormally wet season of 1917. Experiments were conducted in 1918 to determine the material or combination causing the burning. The combinations of arsenate of lead and soap with Bordeaux proved responsible. Wherever the copper sulphate was omitted and the arsenate-soap-lime mixture was used, no injury resulted.

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[1] An appreciable difference was noticed in the length of time required to "wet" the clusters of different varieties. Beginning with Niagaras, which were most readily wet, the other varieties followed in about this order: Catawbas, Delawares, Ives, and Concords. This difference is apparently closely correlated with the waxy bloom on the grape berries.

The burning was closely related to the thrift of vines, the stage of grape growth when sprays were applied, the weather during and following spray aplications, and the method of mixing materials. Weak vines and those bearing too heavy crops were most seriously burned. Spray applications just before and after bloom caused more injury than later applications. Excessively wet and cloudy weather during and following spray applications appeared to increase burning. When either of the ingredients of Bordeaux was added to the other without being diluted, increased burning resulted.

From the above observations it is concluded that Bordeaux mixture should not be used in the arsenate of lead-soap combination on the Ives variety at any time and that in applying the combination with Bordeaux to Concords and Catawbas the above factors influencing foliage injury should be kept in mind. The arsenate of lead-soap-lime mixture was safe wherever used, even on the Ives variety. The injury from spray materials appears to be cumulative from season to season. The combinations of spray materials and factors influencing grape foliage injury warrant further experimentation.

Dusting for Control of Grape-Berry Moth.

Much interest is centering in the application of insecticides and fungicides in dust form as compared with the liquid application. In an attempt to avoid all spray residue on grapes at harvest time, grape-dusting experiments were conducted in 1916, 1917, and 1918. The final infestation in check plats adjacent to the dusted plats was so light as to give inconclusive results except in 1916. The plan of the 1916 experiments and the results recorded are presented in Table IX.

Table IX.—*Dusting experiment for control of grape-berry moth, Schonhardt Vineyard, Venice, Ohio, 1916.*

Plat No.	Dust and spray mixtures used and dilutions.	Spray applications.		Counts of infested grapes at harvest, Oct. 13, 1916.					
		3 to 5 days after grapes bloom, June 29.	When second-brood larvæ begin to hatch, Aug. 4.	Number of vines examined.	Number of clusters examined.	Number of grapes examined.	Number of clusters infested.	Number of grapes infested.	Percentage of grapes infested.
1	Arsenate of lead powder, 2½ pounds to 50 gallons; Bordeaux, 3-3-50; laundry soap, 2 pounds to 50 gallons. Liquid application	X	....	....	....	....	....	....	....
	Dust mixture, arsenate of lead powder 10 per cent, hydrated lime 90 per cent	....	X	8	211	6,330	211	2,978	47.04
2	Arsenate of lead powder, 2½ pounds to 50 gallons; Bordeaux, 3-3-50; laundry soap, 2 pounds to 50 gallons	X	X	6	215	6,450	202	1,194	18.51
3	Check unsprayed	....	....	8	239	7,170	239	5,668	79.05

The dust materials were applied with a small hand duster and the liquids with a gasoline power sprayer. In each case the application was made from either side of each row and a thorough covering of foliage and fruit effected. The dust materials adhered to the grape foliage fairly satisfactorily but did not adhere well to the smooth surface of the grape berries. No rain fell from the time of the application until August 11 when a light shower occurred. When the vines were examined on August 19 only a trace of the dust material was in evidence on the foliage or fruit, while the sprayed fruit was well covered with spray material. It required 40 pounds of dust material to dust 46 thrifty Catawba vines. At this rate and with the vines set 900 to the acre as is the practice in this section, it would require 783 pounds of material per acre. No doubt this would be materially reduced if a power machine were used for the dusting. If but half as much material were required per acre the amount of arsenical would be from 6 to 7 times as great as when applied in liquid form at the rate of 1½ pounds of arsenate of lead powder to 50 gallons of spray and the liquid applied at the rate of 200 gallons per acre. The writers feel that the dust would have to be applied much more frequently than the liquid to be effective for berry moth control. This method of application might be satisfactory for treating small home grape arbors when applied frequently.

Spray Residue on Grapes at Harvest Time.

Throughout these investigations records were kept on the comparative amounts of spray residue on the grapes at harvest time. In all cases where the spray application shown as the third (fig. 1) was used in early August the fruit was heavily coated with spray material at harvest time. In nearly all cases where the combination of first and second sprays was used, and spraying completed by July 25, there was not sufficient spray residue at harvest time to affect the marketing of the grapes in baskets for table use. When either the first or second application was used alone the residue was lighter than when both were used. Slightly more residue resulted on the plats sprayed with arsenate of lead at the rate of 2½ pounds than on those sprayed with the same material at the rate of 1½ pounds to 50 gallons. No difference could be seen between the fruit from plats on which Bordeaux was included and those on which lime, 2 pounds to 50 gallons, was substituted for it. Slightly less residue was present on the plats sprayed with arsenate of calcium than on those sprayed with arsenate of lead where the comparison of material was on the basis of arsenical content. In one plat where these materials were mixed in the proportion of arsenate of calcium 9 ounces to arsenate of lead 5 ounces, the amount of residue was

greater than where arsenate of calcium was used alone and less than where arsenate of lead was used alone.

SUMMARY OF RESULTS WITH SPRAY MATERIALS.

Arsenicals.—Arsenate of lead powder at the rate of 1½ pounds to 50 gallons proved adequate for commercial control of the grape-berry moth in the average case. Arsenate of calcium proved almost equally as efficient as arsenate of lead when compared on the basis of arsenical content and has the additional advantage of leaving less residue at harvest time.

Spreaders and adhesives.—Resin fish-oil soap at the rate of 1 pound to 50 gallons possessed all the qualities desired and required 33 per cent less spray material than laundry soap and 86 per cent less than soft soap, to wet the grape clusters on an equal area of vineyard.

Spray combinations.—The mixture of arsenate of lead and soap with Bordeaux should be used with care on Catawba and Concord varieties. The Bordeaux mixture should be omitted on the Ives variety. Stone lime at the rate of 2 pounds to 50 gallons should be added to the arsenate of lead-soap combination when Bordeaux mixture is omitted.

Dust mixtures.—The dust mixture of arsenate of lead and hydrated lime did not adhere to the grape clusters as well as the liquid sprays. The dust material was only partially effective for the control of the grape-berry moth.

Spray residues.—Objectionable residues do not result when the first and second spray applications are used with care. A spray application in August with the materials necessary for berry-moth control will leave a residue which will bar the fruit from the basket market.

COST OF TRAILER SPRAYING.

Because of the fan training system it was necessary, when spraying, to drive between each two rows of grapes. Each rodman sprayed but one side of one row at a time. In the Chautauqua-Erie belt it was found possible for a man to spray both sides of a row as he went, but there appears to be little gain in time by the latter method. In all of the experimental work it was found possible to mix and apply 6 tank loads of 150 gallons each or a total of 900 gallons in 9 working hours. This amount of material covered from 3 to 8 acres, depending on local conditions, and averaged about 5 acres. About one-half more material was required for the second application than for the first. Where the third application was made on plats that had received the second, the amount was about the same as for the

first application, but where the second had not been applied slightly more material was required for this third application than for the second application in adjoining plats. This difference is accounted for by the fact that the material from the second application remains on the grapes and overcomes the waxy bloom, thereby allowing quick wetting.

The following comparisons of single-nozzle, double-nozzle, and spray-guns for use in trailer spraying were made:

TABLE X.—*Experiments with single and double nozzles and spray guns for use in trailer spraying of grapes. E. Dunning's vineyard, Avon Lake, Ohio, 1918.*

[First spray application for grape-berry moth control, June 19.]

Plat No.	Number nozzles per rod.	Nozzle apertures.	Pressure per square inch.	Time to spray 150 gallons.	Number rows sprayed.	Percentage of time saved.	Percentage of material saved.
		Inches.	*Pounds.*	*Minutes.*			
1	1	$\frac{1}{8}$	175	64	14	0	0
2	2	$\frac{1}{16}$	175	50	16	21.8	14.2
3	(1)	$\frac{1}{8}$	200	38	16	40.6	14.2

[1] Spray guns, 1 to each hose line.

In Table X it is seen that two medium nozzles per rod saved 21 per cent in time and 14 per cent in materials as compared with one large nozzle. Spray guns saved 40 per cent in time and used no more material than two nozzles per rod, but an angle at the nozzle end of a rod is a necessity for thorough covering of the grape clusters. The writers believe that for the average vineyard two disk nozzles, at an angle of 45°, to each rod, with $\frac{1}{16}$-inch apertures and a pressure of 175 pounds, will be found most satisfactory.

Materials and labor vary so greatly from season to season and in local sections that figures as to the cost of spraying are of little value. The statement can be made that an average of about 5 acres of thrifty vineyards can be sprayed by two men with a team in a day and will require from 100 to 250 gallons, averaging 147 gallons (Tables I and II) per acre for the first application, and from 160 to 300, with an average of 224 gallons per acre, for the second application.

CONCLUSIONS.

The grape-berry moth has been a more general pest in northern Ohio than in other commercial grape sections because of the following conditions: (1) Production of the late maturing Catawba variety, (2) cultural methods favorable to successful wintering of the insect, (3) harvesting methods which leave the insect in the vineyards, (4) a grape training system which prevents spray materials from reaching the clusters when applied with set nozzles.

Spray schedule.—The combination of first and second spray applications is adequate for control on the principal varieties of grapes grown in northern Ohio and when carefully applied leaves the fruit suitable for the basket market.

Spray materials.—A combination of arsenate of lead powder 1½ pounds to 50 gallons and resin fish-oil soap 1 pound to 50 gallons, in Bordeaux mixture or with stone lime 2 pounds to 50 gallons, may be used for spraying Concords and Catawbas. Copper sulphate should not be used in the above mixture for Ives variety. Arsenate of calcium, commercial powder, proved almost as efficient as arsenate of lead for grape-berry moth control. Dust mixtures do not adhere to the grape berries as well as liquid sprays but may be used on small home grape arbors if applied frequently.

Spray residues.—The grapes will be practically free from spray residue if the schedule recommended is used according to directions.

Spray method.—The trailer method only was used, and a trailer provided with a short rod and two angle nozzles proved most satisfactory in most vineyards.

RECOMMENDATIONS.

When possible, vineyards should be placed in condition for winter at the end of the cultivation season in July and left without further cultivation until spring; this practice is designed to increase the winter mortality of the grape-berry moth pupæ.

Number of spray applications.—For general practice for grape-berry moth control in northern Ohio two spray applications should be made.

Time.—The first application should begin 3 to 5 days after grapes set and the second should begin when the grapes touch in the clusters. This second application will usually come 3 to 4 weeks after the first.

Method.—Where the berry moth is a major pest the trailer method of spraying is the only one that will give complete control.

Materials.—Arsenate of lead, at the rate of 1½ pounds of powder or 3 pounds of paste to 50 gallons, as the active killing agent, with resin fish-oil soap, at the rate of 1 pound to 50 gallons, for a spreader and adhesive, used either in Bordeaux mixture or with 2 pounds of freshly slaked lime to each 50 gallons, has proved the most consistent combination tried. Bordeaux mixture should not be used on the Ives variety of grapes in northern Ohio because of the danger of injury to the foliage. Amounts of material should be great enough to allow the covering of all clusters with a thin, smooth film of spray material.

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